Report by the CHARMED MESONS Working Group

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Abstract

The main topic of discussion was decays of excited charmed mesons. The group discussed the current status of knowledge about the excited states of charmed mesons, the problems encountered in the study of these states, and measurements on the excited states that would be desirable in the near future. The other topics discussed were charm production, and W-emission for ΔS=1 and ΔC=1 weak decays.

1 EXCITED CHARMED MESONS

Charmed mesons are useful for testing our ideas about the quark model and about QCD via the quark model. As pointed out by DeRujula, Georgi and Glashow [1] in 1976, for a meson containing a heavy and a light quark, as the mass of the heavy quark increases, the properties of the meson are determined increasingly by the dynamics of the light quark, and approach a universal limit. There is some recent theoretical work, for example that by Eichten, Hill and Quigg [2] and that by Godfrey and Kokoski [3], that analyzes data on charm mesons using this Heavy Quark Symmetry. Experimental information on the properties of charmed mesons is useful for developing and testing these models.

A better knowledge of the characteristics of charmed mesons also helps the understanding of B-mesons [4]. The models using Heavy Quark Symmetry use the observations on charmed mesons to predict the properties of the B-mesons [2]. Experimental measurements on B-mesons require a knowledge of the properties of the charmed mesons because B-mesons usually decay to charmed mesons.

1.1 Difficulties in Observing Excited States

While the properties of the L=0 charmed mesons (1S states) are fairly well understood, the spectroscopy of the L=1 mesons (2P states) is in its beginning stages, and none of the higher excited states (the 2S, 3D, etc.) has been observed. The excited charm states are expected to decay strongly, either directly or through other excited D-mesons, to one L=0 D-meson and one or more lighter mesons. They are more difficult to observe and analyze than the L=0 mesons because they are not produced as copiously, and are wider. The combinatoric background under the peak is also worse, partly due to the larger width of the states, and partly because they have a larger number of particles at the end of their decay chains.

In fixed target experiments, there is an additional reason for a higher combinatoric background in case of the excited D-mesons. Unlike the case of weak charm decays, the decay vertex cannot be distinguished from the production vertex. Hence, the mass combination hypotheses will include tracks other than those actually associated with the decay. As a result, there is a higher combinatoric background, which gets worse with increasing multiplicity in the primary vertex (the vertex associated with the production of charm). Since multiplicity in the primary vertex generally is higher when the charm is produced by hadroproduction as opposed to photoproduction, a photoproduction experiment is likely to have smaller combinatoric background.

There are other difficulties associated with the larger width of the excited D-mesons than just a larger statistical uncertainty resulting from a higher combinatoric background under the peak. One of them is the systematic error in the determination of the magnitude and shape of the background. The standard method to observe a new state is to look for a peak over a smooth background in a mass plot. The background under the peak is obtained by interpolating between two regions on either side of the peak with the assumption that the background varies in a smooth simple fashion (usually parametrizable with up to four or five parameters). For a reliable determination of the background one needs a wide enough window around the peak ($\approx$ 6 times the full width of the state if the width is much larger than the resolution of the mass measurement, and $\approx$ 10 times the resolution if the width is narrow).

If the state being investigated is wide, it is difficult sometimes to find such a window, because of structures near the peak due to other states (partially or fully reconstructed), or from the state being investigated, if it is only partially reconstructed. For example, when looking for the decay $D_2^{*0}(2460)$ to $D^+\pi^-$ in the difference mass distribution $\Delta M = M(D^+\pi^-) - M(D^+)$, one sees a peak at $\Delta M \approx 590$ MeV/c^2 arising from the decay of $D_2^{*0}(2460)$ to $D^+\pi^-$, and an additional bump at $\Delta M \approx 420$ MeV/c^2 due to the decays $D_2^{*0}(2460)$ and $D_1^0(2420)$ to $D^{*+}\pi^-$, with the D^{*+} decaying to $D^+\pi^0$ [5]. If all such structures were caused by known states, they could be dealt with. Unfortunately, many of them are due to heavier states which have not yet been observed or are not very well understood. These structures are more likely to be a problem if they are of a width comparable to that of the state being investigated. A very wide structure would provide a smooth background under the peak. A very narrow structure usually does not affect the determination of the characteristics of the peak, unless it is very close to the peak (within $\approx$ one full width of the center of the peak). If the narrow structure was tall enough to affect the background determination it would be easy to identify and deal with.

Sometimes peaks due to two states can overlap. The analysis in that case becomes more complicated, especially if one does not have any a priori knowledge about any of the states. An example is the peaks due to the $D_1^0(2420)$ and $D_2^{*0}(2460)$ in the $D^{*+}\pi^-$ mass distribution.

In such cases, one attempts to find another decay mode in which the peak is more isolated. In the particular case of $D_2^{*0}(2460)$, one looks for the state in the decay $D_2 \rightarrow D^+\pi^-$. Additional information about the decay (for example, the helicity information in the above case [5]) can also be used to disentangle the overlapping states.

1.2 Current Status

For a given pair of quarks, $c\bar{u}$, $c\bar{d}$, or $c\bar{s}$ with orbital angular momentum L=1, there are three total angular momentum states, $J^P=0^+$, 1^+, and 2^+, corresponding to the value S=1 for the sum of the quark spins. There is one state, $J^P=1^+$, corresponding corresonding to S=0. The 2^+ states have been observed for all three quark pairs $c\bar{u}$, $c\bar{d}$, and $c\bar{s}$. The two J=1 states are expected to mix. One of the two observable states after the mixing is expected to be narrow and the other is expected to be relatively wide (Γ >200 MeV) [3]. The narrow state has been observed for $c\bar{u}$ and $c\bar{s}$. The full reconstruction of the J=1 $c\bar{d}$ state, which decays to $D^{*+}\pi^0$ or $D^{*0}\pi^+$, but not to $D^+\pi^0$ or $D^0\pi^+$, requires efficient detection of a π^0. In a fixed target experiment, a decay to a π^0 has a higher background than a decay to a π^+ because the direction of a potential π^0 track is not as well known as that of a π^+ track. The rest of the L=1 states have yet to be observed. Most of them are expected to be fairly broad [2][3]. The 2S states or states with higher radial excitations have not been observed either.

1.3 Measurements to be made

1.3.1 Branching Fractions

More decay modes of the known states have to be observed and the branching fractions for the various decays measured. One decay mode that seems to be especially important for measurements on B-decays is the decay of the L=1 D-mesons to Dρ. Even though the central value of the ρ mass is too high to allow a decay of an L=1 D-meson to Dρ, the large width of the ρ is expected to result in a significant branching fraction to Dρ [6]. Full reconstruction of this decay might require some special attention during the design of a detector.

The information on branching fractions, for example, Γ ($D_2 \rightarrow D^+\pi^-$) / Γ ($D_2 \rightarrow D^{*+}\pi^-$), has large uncertainties and many theoretical predictions remain plausible. A better measurement of these fractions is needed to help develop the details in the theoretical models and increase the reliability and accuracy of their predictions. A better knowledge of the branching fractions also helps measurements on B-mesons, due to the decay of B-mesons to excited D-mesons.

1.3.2 Widths

The widths of the observed L=1 states have a large uncertainty. The uncertainty in the width due to a systematic uncertainty in the background under the peak is, in all cases, comparable to the statistical error. With higher statistics available, more excited states are expected to be observed and understood. This should lead to a better understanding of the reflections they cause in the various mass plots used to observe the L=1 mesons. A better understanding of the background would in turn enable a better measurement of the widths of these states.

When obtaining the ratio of the number of events, a large part of the error in the ratio comes from the uncertainty in the shape of the peak. Thus a better measurement of the width of the peak would result in a better measurement of the number of events in the various decay modes and hence of the branching fractions.

1.3.3 Observation of New States

Most of this discussion centered around the items in the D** Shopping List of Eichten, Hill and Quigg [6]. The radially excited states in the list are wider than the L=1 states observed so far. The 3D and 2P states are 400 MeV heavier than the 2P states. They are probably too heavy to observe at CLEO. One might be able to observe them at the Fermilab experiments E687 and E791, depending on how well the background can be handled. If one intends to observe them in a future experiment through decays to other excited states one should make sure that the apparatus has a satisfactory acceptance for capturing the decay products of these excited state. For example, if one intends using decays through D*, it should be noted that a soft pion from a D* can be swept out by a magnetic field quite easily, and the apparatus might have a bad acceptance for D* while being efficient at reconstructing ground state D-mesons.

2 Charm Production

Study of charm production provides a means to test QCD via production models. The mass of the charm quark places it in a unique position, where it can provide a link between perturbative and nonpertubative QCD. Charm production data is starting to reach new kinematic regions where it can distinguish between the various theoretical predictions.

J/ψ hadroproduction at large x_f by Fermilab experiment E789 [7] was discussed. J/ψ production at large x_f is especially interesting because the production cross section at large x_f has appreciable contribution from quark-antiquark annihilation (gluon-gluon fusion dominates the total cross section elsewhere). The results from E789 indicate a negligible contribution to the cross section from intrinsic charm [7]. FNAL experiment E791 [9] will have a sample of high x_f open charm mesons which will allow further investigation of hadroproduction. It is important to have a high statistics experiment in the near future that can probe these newly explored regimes more effectively.

3 Weak Decays

Michael Scadron talked about W-emission for ΔS=1 and ΔC=1 weak decays. The talk is written in a report in these proceedings [8].

4 Summary

The group concentrated most of its efforts on discussing the existing and intended measurements on the excited charmed mesons. Many of the problems associated with these measurements were identified as a first step towards planning future measurements on these excited states.

References

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